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LENGTH-WEIGHT RELATIONSHIP, CONDITION FACTOR AND SOME REPRODUCTIVE ASPECTS OF NILE TILAPIA, *OREOCHROMIS NILOTICUS*, IN LAKE HAYQ, ETHIOPIA

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ABSTRACT

Reproduction, length-weight relationship, and condition factor, of *O. niloticus* in Lake Hayq, Ethiopia were studied with the objective of generating life history traits important for sustainable exploitation, management and conservation of the species. 931 samples were collected by beach seine and gillnets of various mesh sizes (3, 5, 6, 8 and 10 cm) from August 2008 to March 2009. Females predominated over males in the total samples (sex ratio=1.25:1, χ^2= 11.84). Length at first maturity was 14.5 cm for females and 15.5 cm for males. Fecundity ranged from 290 to 1287 eggs for fish of 11.5 and 27 cm total length (TL). The relationship between fecundity (F) and total length (TL) and total weight (TW) were described by the equations: Log F= 0.22+1.91 Log TL and F= 113 + 2.60 TW. The average sizes of both sexes were 16.03 cm (± 0.14 SE) TL and 72.2 (± 2.14 SE) gram in weight. The slope *b* of the length-weight relationship was 2.92 for males and 2.97 for females. Growth was isometric in both cases and was not significantly different from the expected value of 3 (t-test, p>0.05). Furthermore, the relationship was highly significant (ANOVA, P< 0.001). The corresponding equations were represented by: Log TW= 2.92 LogTL-1.62 (males) and Log TW= 2.97 LogTL-1.72 (Females). The overall mean FCF obtained for *O. niloticus* in this study is within the range of 1.57-1.93 with a total mean of 1.81. The mean FCF of males and females was 1.84 and 1.78, respectively.

KEYWORDS: FCF: Fecundity, Gondal Stages, Isometric Growth, Maturity Length

INTRODUCTION

Ethiopia is uniquely rich in water resources. It has numerous water bodies including ponds, lakes, rivers, reservoirs and wetlands covering an estimated surface area of 18587 km^2 (Ethiopian Environmental Protection Authority, 2010). These water bodies have been estimated to give a refuge for more than 150 fish species in 29 families (Abebe Getahun, 2007). In 2001, the national annual potential fish production from the main lakes and rivers was estimated to be 51,481 tonnes. The total catches in the same year was 15, 389 tonnes which constitute 30% of the potential yield (LFDP, 1995). Nile tilapia, *Oreochromis niloticus,* is a popular species among bony fishes in Africa including Ethiopia which is one of the most important cichlids for commercial and subsistence fisheries (Skelton, 2001). In Ethiopia, the species constitutes a large portion of the capture fishery and the commercial inland fish catch (Abebe Getahun, 2007).

The breeding condition of tilapia in equatorial waters occurs year round, but they have exhibited a well defined peak breeding period associated with environmental factors (Lowe-McConnell, 2005). The peak breeding time of the species has been synchronized with temperature, light intensity, lunar cycle, rainfall, and seasonal flooding (Fryer and Iles,

1972) and phytoplankton biomass increase (Demeke Admassu, 1996). Fecundity in Nile tilapia has been found to be very variable and determined by the weight, length, gonad weight, age and condition of the fish. It is affected by biotic and abiotic factors (Beveridge and McAndrew, 2000; Ross, 2000). The total number of eggs produced and fertilized per breeding time is not very large. It is proportional to the body weight and length of the female. For example, the fecundity of *O. niloticus* in the wild has been found to be between 905 to 7619 oocytes for fish of 28 to 51 cm total length (Njiru *et al*, 2006). Although Nile tilapia does not produce considerable progeny at each spawning, it provides it's young with a maximum maternal attention and combined with extended reproductive periods each year, maternal attention minimizes the risk of predation and increases survival of offspring (Fryer and Illes, 1972). The condition and growth patterns of a fish can be obtained from its length-weight relationship (Begenal and Tesch, 1978). If length increases in equal proportions with body weight for constant specific gravity, fish are said to exhibit isometric growth. The slope for isometric growth is 3 and values significantly greater or lesser than 3 indicate allometric growth (Ricker, 1975). The slope 'b' is affected by stage of sexual maturity, nutritional adequacy of the diet, and toxicology of the environment (Begenal and Tesch, 1978). Condition factor gives some information about food supply, timing and duration of breeding, as it is also used to assess the well being of the fish (Demeke Admassu, 1990).

Lake Hayq is a highland freshwater lake and located some 450 km far from the capital, Addis Ababa. The catchment and shore of the lake have been highly degraded (Seyoum Mengistou, 2006). The degradation of the lake shore and grazing of macrophytes by cattle destroys the availability of spawning habitats of *O. niloticus* and other fish species. Njiru *et al*. (2006) reported that the knowledge of the life history parameters of fishes is essential to envisage population stability and fluctuations. For example, reliable data on fish reproduction can be used to design effective fisheries management measures such as closed fish areas or seasons. For fish like tilapia such knowledge is particularly important because of the species dependency on shallow, near shore areas for reproduction.

Tilapia was introduced into Lake Hayq in 1978 from a crater lake, probably Lake Hora (Elizabeth Kebede *et al*, 1992). Since then it has quickly established successfully and become commercially important species in the region. The biology of *O. niloticus* from different water bodies in Ethiopia have been studied by various scholars. However, the availability of such biological knowledge is very scarce for the species in Lake Hayq. Therefore, the present study is designed to generate crucial information on sex ratio, fecundity, maturity size, length-weight relationship, condition factor of *O. niloticus* in Lake Hayq. The information would contribute for sustainable utilization, management and conservation of the species.

MATERIALS AND METHODS

Study Area Description

Lake Hayq is located (latitude of $11^0 15'$ N and a longitude of 39^0 57') in northern Ethiopia, at an altitude of 2,030 m (Figure 1).

Table 1: Morphometry and Limnological Parameters of Lake Hayq

Parameters	Values
Max. length (north-south)	6.7[a] km
Max. width	6.0[a] km
Perimeter	21.7[a] km
Area	23.2[a] km^2
Max. depth	88.2 [a]m

Table 1: Contd,

Mean depth	37[a] m
Volume	0.87[a] km^3
Conductivity	923 [c] μscm^{-1}
Salinity	0.828 [c] gL^{-1}
Alkalinity	9.550 [c] $meqL^{-1}$

Sources: Morandini, 1941, cited in Baxtera, 1970; Elizabeth Kebedeb *et al*, 1992; and Zinabu G/Mariamc *et al*, 2002

The surface area, mean and maximum depth of the lake is 23 km^2, 37 m and 88.2 m, respectively and has a volume of 0.87 km^3 (Baxter, 1970). It receives water from many small seasonal streams and one perennial river, Anchercah River, but has no surface outlet and its freshness has been attributed to a possible subsurface outflow towards the west through east-west fractures (Molla Demlie *et al*, 2007). The catchment area of the lake is 65 km^2. The lake has a closed drainage system within the watershed of the Awash River basin (Molla Demilie *et al*, 2007). The water level of the lake fluctuates in relation to seasonal variability in rainfall. The volume of water increases during rainy season and vice versa for the dry season. The water becomes cold in January, February, July and November and it gets warm during April, May, August and September (Kebede Alemu, 1995). Unlike the Rift lakes dominated by Na–HCO_3, magnesium and calcium are important cations in Lake Hayq (Molla Demlie *et al*, 2007). The lake is alkaline having a pH of 9.06 on average and the alkalinity, salinity and conductivity of the lake water are 50 $meqL^{-1}$, 0.828 gL^{-1} and 923 μscm^{-1}, respectively (Zinabu Gebre-Mariam *et al*, 2002).

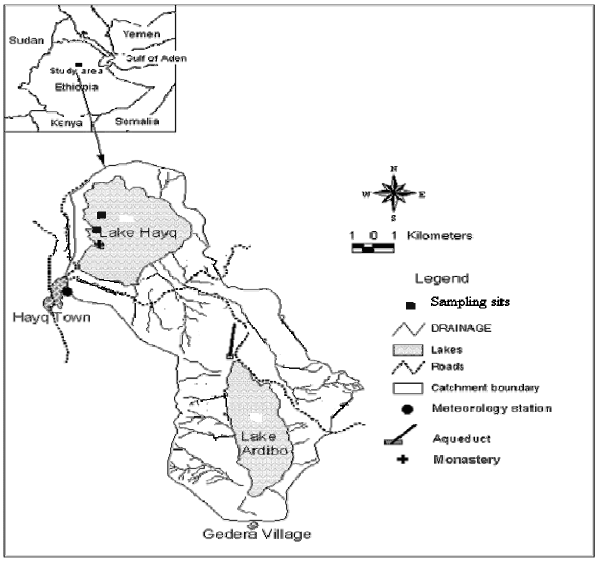

Figure 1: Map Showing Lakes Hayq and Ardibo with Sampling Sites (Modified from Molla Demlie et al, 2007)

The diversity of fish community of Lake Hayq is poor. The current species composition of the lake comprises Nile tilapia, African catfish, Garra spp. and common carp (Abebe Getahun and Stiassny, 2007). The dominant fish species of the lake is Nile tilapia.

Field Sampling and Measurements

Fish samples were collected on monthly basis from August 2008 to March 2009 at two sampling stations (Figure 1). The sampling sites were located near the shore, one with relatively dense macrophyte vegetation and the other open water. Fish were captured by gill nets (stretched mesh sizes of 3, 5, 6, 8, and 10 cm) and beach seines (mesh size 5

mm and 8 mm). In addition, fishermen's catch were also sampled to get a wide range of fish size and to increase the sample size. Soon after collection of fish, total length (TL) and total weight (TW) were measured for each fish using measuring board and digital sensitive balance, to the nearest centimeter and gram, respectively. Each fish was dissected and the sex of the fish was identified through macroscopic examination of gonad stages using keys outlined in Holden and Raitt (1974), and Babiker and Ibrahim (1979). Gonads were assigned to a maturity stage I-V based on five-point maturity scale following Holden and Raitt (1974), Babiker and Ibrahim (1979). Samples of ovaries in maturity stage IV were removed and preserved in a labeled plastic bag containing Gilson's fluid for fecundity estimation (Begenal, 1978). The preserved ripe gonads were taken to Fisheries laboratory, Biology Department, Addis Ababa University, for further investigation.

Reproductive Characteristics

Sex-Ratio and Length at Maturity

The number of females and males were recorded for each month. The female to male ratio was calculated for each month, different size groups and total sample. Then, the sex ratio was assessed using the chi-square test within months, size groups and the total sample if it deviates from 1:1 (Sokal and Rohlf, 1981). Length at sexual maturity of male and female *O. niloticus* was determined using data collected during the study period. Each fish was classified as either sexually immature or sexually mature based on the stage of development of its gonads. Those fish that were grouped in stage I were considered as sexually immature, while those with gonads in stages II, III, IV and V were considered as sexually mature (Tesfaye Wudneh, 1998). Length data were classified into classes of 1 cm interval. The proportion of sexually mature fish and the length at first sexual maturity were determined using graphical method (Tweddle and Turner, 1977).

Fecundity Estimation

The ovary samples of maturity stage IV stored in Gilson's fluid were used for fecundity estimation. The samples were periodically shaken and subjected to serial washing with tap water to get rid of the preservative. The eggs were then counted (Bagenal, 1978). The relationship between fecundity and fish length/weight was described by the equation (Bagenal and, Braun 1978): $\mathbf{F= ax^b}$**;** where, F= fecundity, x= total length in centimeters or total weight in grams, b= slope, and a = intercept. Regression analysis was used to analyze pooled data for relationships between fish size (length/ weight) and fecundity.

Length-Weight Relationship and Condition Factor

Length-weight relationship was estimated employing the equation: $TW= aTL^b$ and was logarithmically transformed into $\log TW = \log a + b\log TL$, where, TW= weight of fish in grams; TL= total length in centimeters; a= intercept and b= slope.

The parameters *a* and *b* of the length-weight relationships were estimated by the least-squares method (Sokal & Rohlf, 1981), using TW as the dependent variable and TL as the independent variable. Student's t-test was applied to verify whether the regression constant "b" is significantly different from 3.0 (Froese, 2006). Fulton's condition factor was calculated using the expression by LeCren (1951): $FCF= (TW/TL^3) \times 100$, Where, FCF= Fulton's condition factor; TW = total weight in grams; TL= total length in centimeters. The mean FCF for the fish in monthly samples was determined by sex. Analysis of variance was used to test for significant differences in mean FCF between months and between sexes.

RESULTS

Size Composition of the Catch

A total of 931 individuals of *O. niloticus* were studied. Their size ranged from 4 to 29 cm in total length. The sizes of the largest male and female were 29 cm and 27 cm TL, respectively. The largest total weight is 423 gram for males and 363 gram for females.

Reproductive Characteristics

Sex Ratio and Length at Maturity

A total 931 *O. niloticus* were studied and 518 (55.6 %) were females and 413 (44.4 %) were males giving a sex ratio of 1.25 females: 1 male (Table 2). This ratio was significantly different from 1: 1 (χ^2= 11.84, $p < 0.05$). Moreover, in March (Table 2) and in length groups of 4-5, 14-15 and 18-19 cm the sex ratio was significantly different from the expected 1:1 in favor of females while in the remaining months and length groups both male and female populations occurred almost in equal proportions ($p > 0.05$).

Table 2: Monthly Numbers of Males and Females and Sex Ratio of *O. niloticus* in Lake Hayq

Month	Female	Male	Sex-Ratio	Chi-Square
August 2008	26	17	1.53:1	1.88
September 2008	21	14	1.50:1	1.40
October 2008	35	24	1.46:1	2.78
November 2008	69	60	1.15:1	0.63
December 2008	87	72	1.21:1	1.42
January 2009	48	47	1.02:1	0.32
February 2009	109	96	1.14:1	0.76
March 2009	123	83	1.48:1	7.77*
Total	**518**	**413**	**1.25:1**	**11.84***

* means significant at 5% level

The smallest sexually mature male was 13 cm TL whereas the same for female was 11.5 cm TL. Based on graphical methods, male *O. niloticus* reached 50 % sexual maturity ($L_{50\%}$) at 15.5 cm TL and females at 14.5 cm TL. Although the sizes of $L_{50\%}$ were not significantly different from each other (χ^2 = 1.33, p > 0.05), females appeared to reach sexual maturity at a relatively smaller size than males.

Fecundity

Fecundity was estimated for 33 females ranging from 11.5 to 27 cm TL and 90 g to 363 g TW. Total fecundity (F) varied widely even among fishes of the same size. Total fecundity ranged from 290 to 1287 with a mean (±SE) of 574 ± 47.05 eggs for the size ranges from 11.5 cm TL (90 grams) to 27 cm TL (363 grams). Moreover, the relative fecundity of the species varied from 18 to 43 with a mean of 27 per length. The corresponding results also fluctuated from 2 to 6 per body weight (gram) with a mean of 3.45 per gram. It was observed that with respect to weight total fecundity increased as the fish increased in weight, while relative fecundity was higher in younger females than older ones.

The length–fecundity relationship was Log F= 0.22+ 1.91 Log TL (R^2= 0.787) (Figure 2) while the weight–fecundity relationship was F=113+ 2.60TW (R^2= 0.814) (Figure 3). The relationship between fecundity and total length were linear and significant (t=10.547, P < 0.05). The relationship between fecundity and total weight also was highly significant (t= 2.53, P =0.017) and the slope was significantly different from cube (3). Based on the correlation coefficient, fecundity was better related to TW (R= 0.902) than TL (R= 0.887).

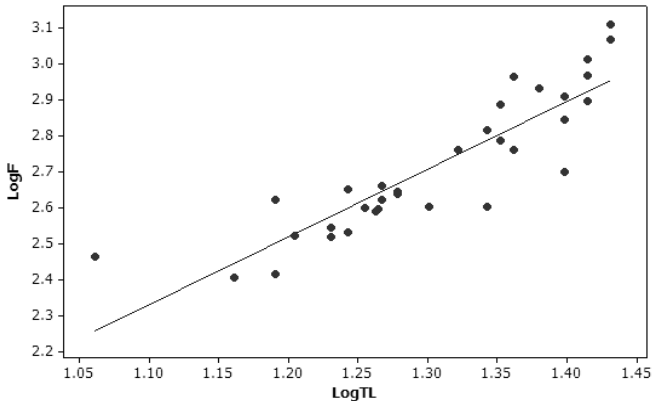

Figure 2: Fecundity (F) and Total Length (TL) Relationship of *O. niloticus* in Lake Hayq

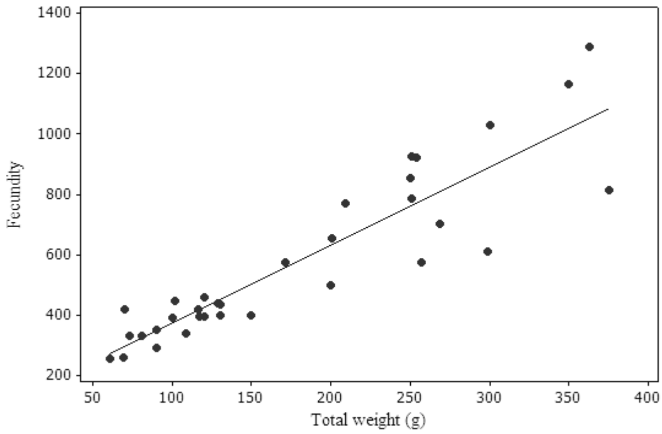

Figure 3: Fecundity (F) and Total Weight (TW) Relationship of *O. niloticus* from Lake Hayq

Proportion of Gonadal Stages

Monthly frequencies of occurrence of *O. niloticus* at various gonad stages are presented in Figures 4 and 5. Female at gonad stage I (immature) and stage II (maturing) were caught at higher frequencies in November and October, respectively (Figure 4). Females with ripening gonads (stage III) were more frequent in December, February and March. Females at stage IV (ripe) occurred throughout the sampling period except in October and December, but their frequency was higher in August, September, January and February. On the other hand, the spent females (stage V) dominated the catch in December and March (Figure 6).

Males with immature and maturing gonadal development were present throughout the study period, but they were more frequent in February and March (Figure 5). Males with ripening gonads were also available in all sampling months except in November but dominated the catch in December and January. Males with ripe gonads were most frequent in February, but none were caught in September and October. No spent male fish was caught in October and November. Relatively high frequency of spent males appeared in August, December and March (Figure 5).

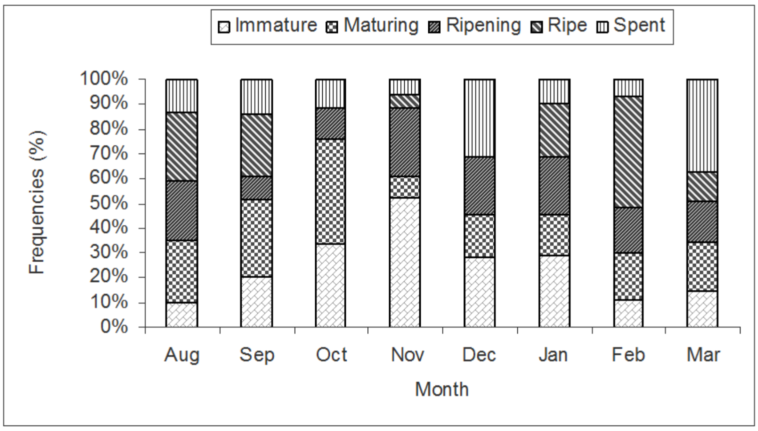

Figure 4: Monthly Gonad Maturity Stages of Female *O. niloticus* from Lake Hayq

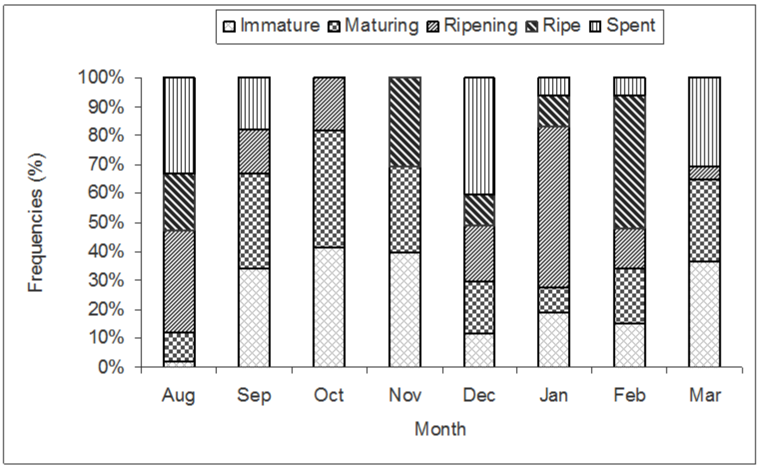

Figure 5: Monthly Gonad Maturity Stages of Male *O. niloticus* from Lake Hayq

Length-Weight Relationship and Condition Factor

Length–weight relationship was separately calculated for the sexes and best described by the following regression equations:

LogTW= 2.97 LogTL- 1.72 (Females; n= 518; r^2= 0.983)

LogTW= 2.92 LogTL- 1.62 (Males; n= 413; r^2= 0.988)

LogTW= 2.95LogTL- 1.69 (Both sexes combined; n=931; r^2= 0.985)

All of the above equations were highly significant ((ANOVA, P< 0.001), the r^2 was above 0.98. Thus, length and weight of *O. niloticus* in Lake Hayq are very well related, and the relationship is curvilinear (or log-linear). The curvilinear curve is shown in Figure 6 for the combined untransformed raw data. The slope (b), or length-weight coefficient, was not significantly different among the three curves (t-test, *p*>0.05). In addition, b was not significantly different from 3 (t-test, *p*>0.05). Thus, the growth of *O. niloticus* in Lake Hayq is isometric as it conforms to the cube law.

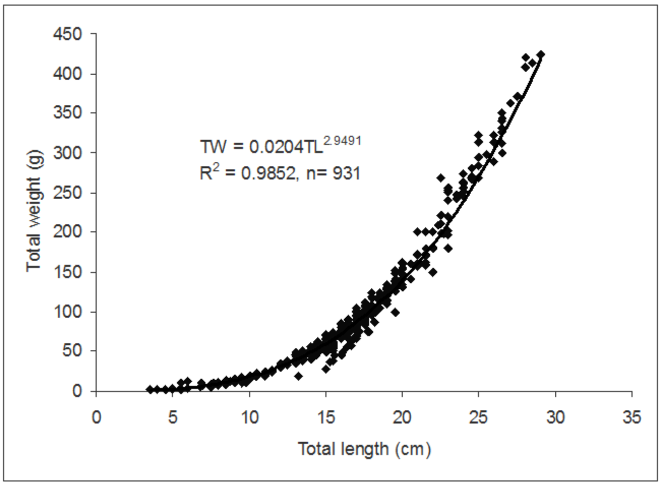

Figure 6: Length-Weight Relationship of Combined Sexes of *O. niloticus* from Lake Hayq

Monthly mean FCF values ranged from 1.74 to 2.01 for males and from 1.39 to 1.87 for females. Mean ± SE FCF of all the males was 1.84 ± 0.035 where as that of all the females was 1.78 ± 0.012. Monthly mean FCF for sexes combined ranged from 1.55 to 1.92 with an overall mean ± SE of 1.81 ± 0.017 (Table 3). Difference in FCF was not significant between sexes (ANOVA, F = 3.24, P = 0.113) (ANOVA, P = 0.002), but highly significant between monthes (ANOVA, P = 0.002). Sex by month interaction was insignificant (ANOVA, *P*>0.05), indicating that FCF temporal variation of both sexes was similar. High FCF for males and females was recorded in March and low values were recorded in September for males and in August for females.

Table 3: Mean Fulton Condition Factor (Mean ±SE) of *O. niloticus* Captured in Monthly Samples from Lake Hayq

Month	FCF	N
August 2008	1.55 ± 0.053	43
September 2008	1.75 ± 0.019	35
October 2008	1.74 ± 0.018	59
November 2008	1.82 ± 0.030	129
December 2008	1.76 ±0.039	159
January 2009	1.79 ± 0.014	96
February 2009	1.81 ± 0.0084	205
March 2009	1.93 ± 0.067	206
All fish	1.80 ± 0.017	931

DISCUSSIONS

The overall sex-ratio (F: M) for *O. niloticus* in Lake Hayq was 1.25:1 which is deviated from the expected 1:1 in favor of females. This agrees with the results obtained for the same species in Lake Awassa (Demeke Admassu, 1994), in Abu- Zabal Lake (Shaloof and Salama, 2008), in Lake Coatetelco, Mexico (Gómez-Márquez *et al*, 2003). On the contrary, sex ratios of the same species where male population dominate over females were reported in Lake Tana (Zenebe Tadesse, 1997) and in Lake Victoria (Njiru *et al*, 2006). Although concrete evidence couldn't be drawn for biased sex ratio for the present study, it may be caused by sexual segregation during spawning, behavioral differences between the sexes, gear type and fishing site (Demeke Admassu, 1994).

The estimated length of 50% maturity ($L_{50\%}$) for females and males of *O. niloticus* in this study was 14.5 and 15.5 cm, respectively. The smallest sexually-mature length was 11.5 and 13 cm for females and males, respectively. Based on macrozone analysis for age estimation of the species in the same lake by Kebede Alemu (1995), the age of the smallest and sexually-mature (50% maturity length) of both sexes was approximately 1 and 2 years, respectively. Hence, both sexes reach sexual maturity at the same age but at different sizes. Although both sexes reach sexual maturity at the same age, the present study shows that male *O. niloticus* in Lake Hayq grows relatively larger than females. Male Nile tilapia typically grows larger than females in small water bodies and riverine habitats (Lowe-McConnell, 1958). Demeke Admassu (1989) found that after 2 years of age female *O. niloticus* grows more slowly than males in Lake Awassa and this may be related to small size of the lake. De Graaf *et al*. (1999) also reported that mean growth rates for males were greater than for females. Onset of sexual maturity could be another factor responsible for differences in sizes at first sexual maturity. Since females invest more energy on reproduction than males, they grow slowly and mature at relatively smaller sizes than males (Demeke Admassu, 1994). The occurrence of larger males may be associated with a system that is dominated by males (Fryer and Iles, 1972) or may be related to high water temperature exposure of young within 15-day post fertilization, as higher temperatures (>34–36 ^{0}C) induce sex-reversal and higher proportions of males (Baroiller *et al*, 1995 cited in Peterson *et al*, 2004).

For the same species length at maturity were 19.8 cm (males) and 18.8 cm (females) in Lake Awassa (Demeke Admassu, 1994), 18 cm for both sexes in Lake Ziway (Zenebe Tadesse, 1988), 42 cm for both sexes in Lake Chamo (Teferi *et al*, 2001), 20.7 (males) and 18.1 cm (females) in Lake Tana (Tesfaye Wudneh, 1998), 11.7 cm (males) and 12.0 cm (females) in Coatetelco Lake, Mexico (Gómez-Márquez *et al*, 2003), 15.1 (females) and 15.2 cm (males) in Emiliano Zapata dam, Mexico (Peña-Mendoza *et al*, 2005). Thus, the lengths at first maturity in Lake Hayq were smaller than those in Lakes Awassa, Tana, Ziway and Chamo and almost equal to population of Zapata dam, but higher than for the rest of the aforementioned water bodies. These differences arise because sexual maturity is a function of the size and age and may be influenced by the abundance and seasonal availability of food, temperature, photoperiod, dissolved oxygen and other environmental factors (Babiker and Ibrahim, 1979; Bwanika *et al*, 2004). Moreover, changes in lake water level and associated factors, poor condition or over fishing (Lowe-McConnell, 1987) lead to a dramatic decrease in size at 50 % maturity. For example, Siddiqui *et al*. (1997) reported that fish size at maturity was influenced by the feeding level as growth is affected by nutrition. Furthermore, predation and competition may be other factors responsible for the small size at first maturity (Bwanika *et al*, 2004). Therefore, the smaller size at maturity of *O. niloticus* in Lake Hayq could be attributed to the small size of the lake, over fishing and slow growth rate compared to Lakes Chamo, Awassa, Tana and Ziway or a combination of any of these factors.

Fecundity ranged from 290-1287 with a mean of 574 eggs corresponding to TL 11.5-27 cm. Comparable results were reported in Lake Awassa (Demeke Admassu, 1994), in Lake Ziway (Zenebe Tadesse, 1988), and in the Coastal Missippi (Peterson *et al*, 2004). However, this result is lower than that reported for the same species in Lake Chamo (mean= 2493 eggs) (Yirgaw Teferi *et al*, 2001) and in Lake Victoria (mean= 2715 eggs) (Njiru *et al*, 2006). It is well known that fecundity values vary even among fishes of the same size, age and species. The above comparative data confirms such proposition. This may be as a result of different adaptations to environmental habitats. In addition, the variation in fecundity may be attributed to differential abundance of food within the members of the population. For example, Siddiqui *et al*. (1997) has shown that fecundity increased with increased feeding levels. Marked differences in fecundity among species often reflect different reproductive strategies (Rideout and Morgan, 2007). Fecundity of *O.*

niloticus is known to vary between size groups and individuals of the same group (Demeke Admassu, 1994). In the present study the same trend was observed. In this respect, Fryer and Iles (1972) concluded that in mouth brooding cichlids, the fecundity is considerably low. Variation in fecundity within the present study might be correlated to differential feeding success among the female fish in the population due to genetic differences. Moreover, the fecundity-length and fecundity-weight relationships observed in this study were log-linear and positive correlation between fecundity and weight ($r = 0.90$) as well as fecundity and length ($r = 0.89$). Though the study confirmed that fecundity was significantly related to both fish length and weight, weight is relatively better related to fecundity than length.

Different gonad development stages were observed throughout the study period (Figures 4 and 5). Similar observations were made for the same species in Lake Awassa (Demeke Admassu, 1996) and in Lake Tana (Zenebe Tadesse, 1997; Tesfaye Wudneh, 1998).

The relationship between length and weight was log-linear and the slope ‘b’ for female, male and combined sexes was 2.97, 2.92 and 2.95, respectively. The value of b for combined data in this study is comparable to the value of b calculated for the same species in Lake Awassa (2.91) (Demeke Admassu, 1990). However, this value is slightly higher than for the same species in Lake Tana (2.74) (Zenebe Tadesse, 1997), in Lake Victoria (3.20) (Njiru *et al*, 2006) and in Lake Turkana (3.17) (Stewart, 1988). According to Bagenal and Tesch (1978) and Froese (2006) the variation in the value of ‘b’ happen due to season, habitat, gonad maturity, sex, diet, stomach fullness, health, preservation techniques and annual differences in environmental conditions.

The overall mean FCF obtained for *O. niloticus* in this study is within the range of 1.57-1.93 with a total mean of 1.81 (Table 3). The study of condition assumes that heavier fish of a given length are in a better condition. The indices have been used by fishery biologists as indicators of the general “well being” or “fitness” of the population under consideration (Jones *et al*, 1999). The values for males, females and the population of the same species were 1.78, 1.58 and 1.68, respectively, in Lake Awassa (Demeke Admassu, 1990), 1.90, 1.88 and 1.89, respectively, in Lake Tana (Zenebe Tadesse, 1997). Therefore, the species in Lake Hayq appear to be comparatively in a better condition than those in Lake Awassa, but lower than those in Lake Tana. However, the data in this study further shows that 99 % of the samples examined had condition factors above one and 32 % had their condition factors above the mean indicating that the majority of the population in Lake Hayq are in a good condition. Comparisons of length-weight equations fitted in the present study with that of Demeke Admassu (1990) and Zenebe Tadesse (1997) could provide more additional evidence. For example, at 20 and 30 cm total length *O. niloticus* may have weights of 156 and 474 grams in Lake Tana, 124 and 383 grams in Lake Awassa and 138 and 461 grams in Lake Hayq, respectively. This comparison shows that the species would be heavier in Lake Hayq than of a similar sized fish in Lake Awassa but lighter than those in Lake Tana. Hence, it can be concluded that *O. niloticus* population has a rapid growth rate in Lake Hayq than in Lake Awassa but slower than that in Lake Tana. In this regard, Kebede Alemu (1995) indicated that the growth rate of tilapia population of Lake Hayq was slightly better than that of Lake Awassa. Later, Demeke Admassu (1998) found that the species grows at a faster rate in Lake Hayq than in Lakes Awassa and Ziway. This difference may be attributed to difference in the availability and quality of food in the different lakes, Lake Hayq may have better productivity with quality food than Lake Awassa, but worse than Lake Tana. However, further study is needed to verify this hypothesis.

In this study males are in a better condition than females. Similar results were reported in Lake Awassa (Demeke Admassu, 1994). The condition factor of both sexes in Lake Hayq was significantly different (ANOVA, $p<0.001$)

among months and was lowest in August for females and in September for males. The seasonal fluctuation was attributed to differences in food supply and quality, feeding rate, degree of parasitization and reproductive activity and abiotic environmental factors such as temperature (Zenebe Tadesse, 1997; Demeke Admassu, 1990; Alemayehu Negassa and Abebe Getahun, 2003).

CONCLUSIONS

In conclusion, Nile tilapia in the lake was highly exploited specially at spawning period. Therefore, the management option for the species should aim at protecting immature males and females so that they can reach breeding size and produce eggs to replenish the stock. Hence, it is recommended to increase the mesh size used to catch fish for lengths greater than 14.5 cm. It has been known that macrophytes provide valuable life support and breeding for fish. However, macrophytes in Lake Hayq have been intensively grazed by cattle along the lake shore, especially during dry seasons. Therefore, the concerned body should take measures to conserve macrophyte beds. In addition, fishing in Lake Hayq is not legally controlled. There is no limitation on the number of fishermen or types of gears used. The exploitation of the lake resources has been increased due to the raised fishing effort. Moreover, it is observed that undersized gillnets are set in the shallow vegetated areas where fish are pushed towards the net by beating the surrounding water and with illegal gillnets encircle a certain shallow area and drag the net and catch fish. Therefore, such situation should be reversed for sustainable utilization.

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